# MEng in Electronic & Computer Engineering

Andrew Whelan, Dublin City University, Prof. Conor Brennan, Dublin City University

Abstract—A heuristic model of diffuse scattering is elaborated and applied to a setup consisting of a plane wave incident on a sinusoidally shaped wall. Results are compared to full-wave method-of-moments (MoM) model, and also to Geometrical Optics (GO) and Physical Optics (PO) approximations.

Index Terms—Diffuse Scattering, Diffuse Reflection, Channel Model, Ray Tracing, Ray Shooting.

## I. Introduction

THIS is the intro.

## II. Models

### A. Effective Roughness Model

This model is a modification of Geometrical Optics in which, in addition to the specular component, each point impinging on the middle of a surface element $dW$ gives a diffuse contribution $dE_d$ to the scattered field $E_s$ whose amplitude $|dE_d|$ is given by

$$|dE_d| \propto \sqrt{\frac{dW \cos\theta_i \cos\theta_d}{\pi}} \frac{1}{r_i r_d} \tag{1}$$

with the constant of proportionality depending on the incident amplitude and a scattering parameter $S$. Specifically, we have

$$|dE_d| = S\Upsilon\sqrt{dW}, \quad \text{where} \tag{2a}$$

$$\Upsilon = \sqrt{\frac{60 G_t P_t \cos\theta_i \cos\theta_d}{\pi}} \frac{1}{r_i r_d} \tag{2b}$$

1) Uniform Plane Wave Incident on PEC: We start with a setup as per Figure 1.

$$k_i = \sin(\theta_i)\mathrm{e}_x - \cos(\theta_i)\mathrm{e}_y \tag{3a}$$

$$k_r = \sin(\theta_i)\mathrm{e}_x + \cos(\theta_i)\mathrm{e}_y \tag{3b}$$

$$k_d = \sin(\theta_d)\mathrm{e}_x + \cos(\theta_d)\mathrm{e}_y \tag{3c}$$

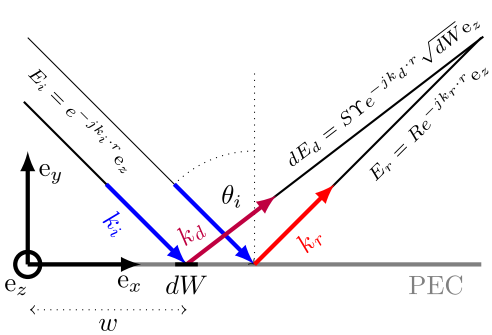


Fig. 1. A uniform plane wave strikes a PEC. The overall scattered wave is $E_s = E_r + \int_W dE_d$. $E_r$ is just the usual specular component of geometrical optics, multiplied by $R$, a roughness parameter. $E_d$ is the diffuse component - a sum of non-coherent contributions along the wall, one of which is shown here, for a drawn surface element $dW$.

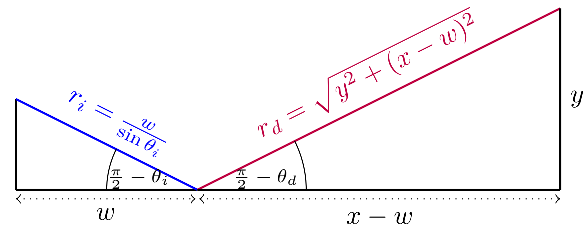


Fig. 2. Geometry setup implies that $\frac{1}{r_i r_d} = \frac{\sin\theta_i}{w\sqrt{y^2+(x-w)^2}}$, and $\cos\theta_d = \frac{y}{\sqrt{y^2+(x-w)^2}}$

Then, since $G_t = 1$ (0 gain), $P_t = 1$ (uniformity of wave), $dW = hdx$, $|\Gamma| = 1$, and referring to the geometry of Figure 2, we get

$$E_i = e^{-j(x\sin\theta_i - y\cos\theta_i)}\mathrm{e}_z \tag{4a}$$

$$E_r = \sqrt{1 - S^2}\; e^{-j(x\sin\theta_i + y\cos\theta_i)}\mathrm{e}_z \tag{4b}$$

$$E_d = S\;\sin\theta_i \sqrt{\frac{60hy\cos\theta_i}{\pi}} \int_W \frac{1}{w}\sqrt{\frac{dw}{(y^2+(x-w)^2)^{\frac{3}{2}}}}\, e^{-j\left(\frac{x^2+y^2-xw}{\sqrt{y^2+(x-w)^2}}\right)}\mathrm{e}_z \tag{4c}$$

## References

[1] V. Degli-Esposti "A diffuse scattering model for urban propagation prediction", IEEE Transactions on Antennas and Propagation, vol. 49, no. 7, pp. 1111-1113, July 2001.

[2] V. Degli-Esposti, F. Fuschini, E. M. Vitucci and G. Falciasecca, "Measurement and Modelling of Scattering From Buildings", IEEE Transactions on Antennas and Propagation, vol. 55, no. 1, pp. 143-153, Jan. 2007.

[3] F. Mani and C. Oestges, "Ray-tracing evaluation of diffuse scattering in an outdoor scenario", Proceedings of the 5th European Conference on Antennas and Propagation (EUCAP), Rome, Italy, 2011.

[4] Hossein Ragheb, Edwin R. Hancock, "The modified Beckmann–Kirchhoff scattering theory for rough surface analysis", Pattern Recognition, Volume 40, Issue 7, 2007, Pages 2004-2020, ISSN 0031-3203.

[5] F. Sheikh, D. Lessy and T. Kaiser, "A Novel Ray-Tracing Algorithm for Non-Specular Diffuse Scattered Rays at Terahertz Frequencies", 2018 First International Workshop on Mobile Terahertz Systems (IWMTS), Duisburg, Germany, 2018, pp. 1-6.

[6] F. Sheikh and T. Kaiser, "A Modified Beckmann-Kirchhoff Scattering Model for Slightly Rough Surfaces at Terahertz Frequencies", 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Atlanta, GA, USA, 2019, pp. 2079-2080.

[7] E. M. Vitucci, N. Cenni, F. Fuschini and V. Degli-Esposti, "A Reciprocal Heuristic Model for Diffuse Scattering From Walls and Surfaces", IEEE Transactions on Antennas and Propagation, vol. 71, no. 7, pp. 6072-6083, July 2023.

[8] V. Degli-Esposti, D. Guiducci, A. de'Marsi, P. Azzi and F. Fuschini, "An advanced field prediction model including diffuse scattering", IEEE Transactions on Antennas and Propagation, vol. 52, no. 7, pp. 1717-1728, July 2004.

[9] M. Zhu, L. Cazzella, F. Linsalata, M. Magarini, M. Matteucci and U. Spagnolini, "Toward Real-Time Digital Twins of EM Environments: Computational Benchmark for Ray Launching Software", in IEEE Open Journal of the Communications Society, vol. 5, pp. 6291-6302, 2024.

[10] Bilibashi, Denis & Vitucci, Enrico & Degli-Esposti, Vittorio, "On Dynamic Ray Tracing and Anticipative Channel Prediction for Dynamic Environments". IEEE Transactions on Antennas and Propagation. PP. 1-1. 10.1109/TAP.2023.3262155, 2023.